

TUFTED FIBROUS WEB

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CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of prior copending U.S. application No.
10 10/435,996, filed May 12, 2003, which is a continuation-in-part of prior copending U.S.
application No. 10/324,661, filed December 20, 2002.

FIELD OF INVENTION

This invention relates to fibrous webs such as woven and nonwoven webs. In particular,
15 this invention relates to fibrous webs treated by mechanical formation to have increased softness
or bulk properties.

BACKGROUND OF THE INVENTION

Fibrous webs are well known in the art. For example, woven webs such as textile and
knit fabrics are well known as material for clothing, upholstery, drapes, and the like. Also,
20 nonwoven webs such as webs formed from polymer fibers are well known as materials useful for
disposable products such as facing layers on absorbent articles such as diapers, for example.

In many applications it is desirable that fibrous webs have a bulky texture and/or softness.
For example, textile wovens known as terry cloth have a bulky texture and softness and are often
used for bath towels, wiping cloths, bibs, clothing, and upholstery fabric. Terry cloth is woven on
25 specially made weaving machines, such as rapier weaving machines. Terry cloth is characterized
by tufted loops of thread, and the tufts can be varied in number and density of loops. However,
terry cloth is relatively expensive due to the relatively complex and expensive weaving machines
necessary for its manufacture. The expense of terry cloth makes it commercially unfeasible for
many applications, particularly for articles intended for limited use, such as disposable absorbent
30 articles.

Attempts have been made to produce a nonwoven fabric having the appearance of terry cloth. For example, U.S. Patent No. 4,465,726 and U.S. Patent No. 4,379,799, both to Holmes et al., describe an apertured, ribbed terry cloth-like nonwoven fabric produced by fluid entangling of fibers on a special forming belt. Even if apertures could be avoided in the method disclosed in
5 Holmes et al., it is well known that fluid entangling is a relatively expensive process for manufacture of nonwoven webs, particularly for webs intended for disposable article use. Furthermore, webs formed by fluid entangling typically have been subjected to forces of the fluid in all the regions of the web so that the entire web is subjected to the applied mechanical energy of the fluid forces.

10 Accordingly, there is a need for a low cost fibrous web having terry cloth-like properties.

Additionally, there is a need for a method for relatively inexpensively making a fibrous web having terry cloth-like properties.

Further, there is a need for a low cost method of making a soft, porous web of woven or nonwoven material.

15 SUMMARY OF THE INVENTION

A fibrous web having a first surface and a second surface is disclosed. The web comprises a first region and a plurality of discrete integral second regions, the second regions having at least one portion being a discontinuity exhibiting a linear orientation and defining a longitudinal axis, and at least another portion being a deformation comprising a plurality of tufted fibers integral with but extending from the first region.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a web of the present invention.

FIG. 2 is an enlarged view of a portion of the web shown in FIG. 1.

20 FIG. 3 is a cross-sectional view of section 3-3 of FIG. 2.

FIG. 4 is a plan view of a portion of the web as indicated by 4-4 in FIG. 3.

FIG. 5 is a photomicrograph of a portion of a web of the present invention.

FIG. 6 is a photomicrograph of a portion of the web of FIG. 5.

FIG. 7 is a perspective view of an apparatus for forming the web of the present invention.

25 FIG. 8 is a cross-sectional depiction of a portion of the apparatus shown in FIG. 7.

FIG. 9 is a perspective view of a portion of the apparatus for forming one embodiment the web of the present invention.

FIG. 10 is an enlarged perspective view of a portion of the apparatus for forming the web of the present invention.

5 FIG. 11 is a photomicrograph of a portion of a web of the present invention.

FIG. 12 is a photomicrograph of a portion of a web of the present invention.

FIG. 13 is a photomicrograph of a portion of a web of the present invention.

FIG. 14 is a photomicrograph of a portion of a web of the present invention.

FIG. 15 is a photomicrograph of a portion of a web of the present invention.

10 FIG. 16 is a photomicrograph of a portion of a web of the present invention.

FIG. 17 is a photomicrograph of a portion of a web of the present invention.

FIG. 18 is a schematic representation of a portion of a web of the present invention.

FIG. 19 is another schematic representation of a portion of a web of the present invention.

FIG. 20 is another schematic representation of a portion of a web of the present invention

15 FIG. 21 is a photomicrograph of a portion of a web of the present invention.

FIG. 22 is an enlarged photograph of a portion of the web shown in FIG. 18.

FIG. 23 is a partial cut away plan view of a sanitary napkin of the present invention.

FIG. 24 is a partial cut away perspective view of a tampon of the present invention.

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DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a web **1** of the present invention. Web **1** is formed from a generally planar, two dimensional nonwoven precursor web **20** (shown below with respect to the method of making) having a first surface **12** and a second surface **14**, and having a machine direction (MD) and a cross machine direction (CD) as is commonly known in the art of nonwoven webs. First surface **12** corresponds to first “side” of web **1** and second surface **14** corresponds to the second “side” of web **1**, the term “sides” being used in the common usage of generally two-dimensional webs, such as paper and films. Although the present invention can be practiced with woven webs, in a preferred embodiment precursor web **20** is a nonwoven web and is comprised of substantially

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randomly oriented fibers, that is, randomly oriented at least with respect to the MD and CD. By “substantially randomly oriented” is meant that, due to processing conditions, there may be a higher amount of fibers oriented in the MD than the CD, or vice-versa. For example, in spunbonding and meltblowing processes, continuous strands of fibers are deposited on a support moving in the MD. Despite attempts to make the orientation of the fibers of the spunbond or meltblown nonwoven web “random,” usually a higher percentage of fibers are oriented in the MD as opposed to the CD.

Nonwoven precursor webs **20** can be any known nonwoven webs comprising fibers having sufficient elongation properties to be formed into web **1** as described more fully below. As shown in FIG. 2, web **1** has a first region **2** defined on both sides of web **1** by the generally planar, two-dimensional configuration of the precursor web **20**, and a plurality of discrete second regions **4** defined by spaced-apart deformations **6** and discontinuities **16** which result from integral extensions of the fibers of the precursor web **20**. The structure of second regions **4** is differentiated depending on which side of web **1** is considered. For the embodiment of web **1** shown in FIG. 1, on the side of web **1** associated with first surface **12** of web **1**, second region **4** comprises deformations **6**, each deformation **6** comprising a plurality of tufted, looped, aligned fibers **8** extending outwardly from first surface **12**. Deformations **6** can be described as “tufts” of fibers, and each deformation **6** has a base **5** proximal to the first surface **12**, and a distal portion **3** at a maximum distance from first surface **12**, as shown in FIG. 3. On the side of web **1** associated with second surface **14**, second region **4** comprises discontinuities **16** which are defined by fiber orientation discontinuities on second surface **14** of web **1**. As shown below, in other embodiments of web **1**, the deformations **6** may be described as tufts, or tufted, but may not comprise looped or aligned fibers.

As used herein, the term “nonwoven web” refers to a web having a structure of individual fibers or threads which are interlaid, but not in a repeating pattern as in a woven or knitted fabric, which do not have randomly oriented fibers. Nonwoven webs or fabrics have been formed from many processes, such as, for example, meltblowing processes, spunbonding processes, hydroentangling processes, spunlacing processes, airlaying, and bonded carded web processes. The basis weight of nonwoven fabrics is usually expressed in grams per square meter (gsm) and the fiber diameters are usually expressed in microns. Fiber size can also be expressed in denier. The basis weight of precursor web **20** can range from 10 gsm to 500 gsm, depending on the ultimate use of the web **1**. For use as a hand towel, for example, a basis weight of precursor web **20** of between 25 gsm and 100 gsm may be appropriate. For use as a bath towel a basis weight of

between 125 gsm and 250 gsm may be appropriate. For use as a ground cover, such as a cow carpet, a basis weight of between 350 gsm and 500 gsm may be appropriate. The constituent fibers of nonwoven precursor web **20** can be comprised of polymers such as polyethylene, polypropylene, polyester, and blends thereof. The fibers can comprise cellulose, rayon, cotton, or other natural materials or blends of polymers and natural materials. The fibers can also comprise a super absorbent material such as polyacrylate or any combination of suitable materials. The fibers can be monocomponent, bicomponent and/or biconstituent, round, non-round fibers (e.g., shaped fibers or capillary channel fibers), and can have major cross-sectional dimensions (e.g., diameter for round fibers) ranging from 0.1-500 microns. For example, one type of fibers suitable for the nonwoven web includes nanofibers. Nanofibers are described as fibers having a mean diameter of less than 1 micron. Nanofibers can comprise all of the fibers in a nonwoven web or a portion of the fibers in a nonwoven web. The constituent fibers of the precursor web may also be a mixture of different fiber types, differing in such features as chemistry, components, diameter, shape, and the like.

As used herein, "spunbond fibers" refers to small diameter fibers which are formed by extruding molten thermoplastic material as filaments from a plurality of fine, usually circular capillaries of a spinneret with the diameter of the extruded filaments then being rapidly reduced. Spunbond fibers are generally not tacky when they are deposited on a collecting surface. Spunbond fibers are generally continuous and have average diameters (from a sample of at least 10) larger than 7 microns, and more particularly, between about 10 and 40 microns.

As used herein, the term "meltblowing" refers to a process in which fibers are formed by extruding a molten thermoplastic material through a plurality of fine, usually circular, die capillaries as molten threads or filaments into converging high velocity, usually heated, gas (for example air) streams which attenuate the filaments of molten thermoplastic material to reduce their diameter, which may be to microfiber diameter. Thereafter, the meltblown fibers are carried by the high velocity gas stream and are deposited on a collecting surface, often while still tacky, to form a web of randomly dispersed meltblown fibers. Meltblown fibers are microfibers which may be continuous or discontinuous and are generally smaller than 10 microns in average diameter.

As used herein, the term "polymer" generally includes, but is not limited to, homopolymers, copolymers, such as for example, block, graft, random and alternating copolymers, terpolymers, etc., and blends and modifications thereof. In addition, unless otherwise specifically limited, the term "polymer" includes all possible geometric configurations of the

material. The configurations include, but are not limited to, isotactic, atactic, syndiotactic, and random symmetries.

As used herein, the term "monocomponent" fiber refers to a fiber formed from one or more extruders using only one polymer. This is not meant to exclude fibers formed from one polymer to which small amounts of additives have been added for coloration, antistatic properties, lubrication, hydrophilicity, etc. These additives, for example titanium dioxide for coloration, are generally present in an amount less than about 5 weight percent and more typically about 2 weight percent.

As used herein, the term "bicomponent fibers" refers to fibers which have been formed from at least two different polymers extruded from separate extruders but spun together to form one fiber. Bicomponent fibers are also sometimes referred to as conjugate fibers or multicomponent fibers. The polymers are arranged in substantially constantly positioned distinct zones across the cross-section of the bicomponent fibers and extend continuously along the length of the bicomponent fibers. The configuration of such a bicomponent fiber may be, for example, a sheath/core arrangement wherein one polymer is surrounded by another, or may be a side-by-side arrangement, a pie arrangement, or an "islands-in-the-sea" arrangement, each as is known in the art of multicomponent, including bicomponent, fibers. Bicomponent fibers can be splittable fibers, such fibers being capable of being split lengthwise before or during processing into multiple fibers each having a smaller cross-sectional dimension than the original bicomponent fiber. Splittable fibers have been shown to produce softer nonwoven webs due to their reduced cross-sectional dimensions. Representative splittable fibers useful in the present invention include type T-502 and T-512 16 segment PET/nylon 6 2.5 denier fibers; and type T-522 16 segment PET/PP splittable fibers, all available from Fiber Innovation Technology, Johnson City, TN.

As used herein, the term "biconstituent fibers" refers to fibers which have been formed from at least two polymers extruded from the same extruder as a blend. Biconstituent fibers do not have the various polymer components arranged in relatively constantly positioned distinct zones across the cross-sectional area of the fiber and the various polymers are usually not continuous along the entire length of the fiber, instead usually forming fibrils which start and end at random. Biconstituent fibers are sometimes also referred to as multiconstituent fibers.

As used herein, the term "non-round fibers" describes fibers having a non-round cross-section, and includes "shaped fibers" and "capillary channel fibers." Such fibers can be solid or hollow, and they can be tri-lobal, delta-shaped, and are preferably fibers having capillary channels

on their outer surfaces. The capillary channels can be of various cross-sectional shapes such as “U-shaped”, “H-shaped”, “C-shaped” and “V-shaped”. One preferred capillary channel fiber is T-401, designated as 4DG fiber available from Fiber Innovation Technologies, Johnson City, TN. T-401 fiber is a polyethylene terephthalate (PET polyester).

5 As used herein, the term “integral” as in “integral extension” when used of the second regions 4 refers to fibers of the second regions 4 having originated from the fibers of the precursor web 20. Therefore, the looped fibers 8 of deformations 6, for example, can be plastically deformed and extended fibers of the precursor web 20, and are, therefore, integral with first regions 2 of web 1. As used herein, “integral” is to be distinguished from fibers introduced to or
10 added to a separate precursor web for the purpose of making tufts, as is commonly done in conventional carpet making, for example. It can be appreciated that a suitable nonwoven web 20 should comprise fibers capable of experiencing sufficient plastic deformation and tensile elongation, or are capable of sufficient fiber mobility such that looped fibers 8 are formed. However, it is recognized that a certain percentage of fibers urged out of the plane of the first
15 surface 12 of the precursor web 20 will not form a loop, but instead will break and form loose ends. Such fibers are referred to herein as “loose” or “broken” fibers 18 as shown in FIG. 3. Loose fiber ends 18 can also be the result of forming deformations 6 from nonwoven webs consisting of or containing cut staple fibers. Loose fiber ends 18 are not necessarily undesirable for the present invention, but it is believed that web 1 can retain its bulky and soft character more
20 readily when deformation 6 comprises primarily looped fibers 8. In a preferred embodiment, at least about 50%, more preferably at least 70%, and most preferably at least 90% of fibers urged in the Z-direction are looped fibers 8.

A representative deformation 6 for the embodiment of web 1 shown in FIG. 1 is shown in a further enlarged view in FIG. 2. As shown, deformation 6 comprises a plurality of looped fibers
25 8 that are substantially aligned such that deformation 6 has a distinct longitudinal orientation and a longitudinal axis L. Deformations 6 also have a transverse axis T generally orthogonal to longitudinal axis L in the MD-CD plane. In the embodiment shown in FIGS. 1 and 2, longitudinal axis L is parallel to the MD. In one embodiment, all the spaced apart deformations 6 have generally parallel longitudinal axes L. The number of deformations 6 per unit area of web 1,
30 i.e., the area density of deformations 6, can be varied from 1 deformation 6 per square centimeter to as high as 100 deformations 6 per square centimeter. There can be at least 10, or at least 20 deformations 6 per square centimeter, depending on the end use. In general, the area density need not be uniform across the entire area of web 1, but deformations 6 can be only in certain regions

of web **1**, such as in regions having predetermined shapes, such as lines, stripes, bands, circles, and the like.

As shown in FIG. 2, and more clearly in FIGS. 3 and 4, one characteristic of the fibers **8** of deformations **6** in one embodiment of web **1** is the predominant directional alignment of the looped fibers **8**. As shown in FIGS. 3 and 4, the looped fibers **8** have a substantially uniform alignment with respect to transverse axis **T** when viewed in plan view, such as in FIG. 4. By “looped” fibers **8** is meant that fibers **8** begin and end in web **1**. By “aligned” with respect to looped fibers **8** of deformations **6** is meant that looped fibers **8** are all generally oriented such that, if viewed in plan view as in FIG. 4, each of the looped fibers **8** has a significant vector component parallel to the transverse axis **T**, and preferably a major vector component parallel to the transverse axis **T**. As used herein, a looped fiber **8** oriented at an angle of greater than 45 degrees from the longitudinal axis **L** when viewed in plan view, as in FIG. 4, has a significant vector component parallel to the transverse axis **T**. As used herein, a looped fiber **8** oriented at an angle of greater than 60 degrees from longitudinal axis **L** when viewed in plan view, as in FIG. 4, has a major vector component parallel to the transverse axis **T**. In a preferred embodiment, at least 50%, more preferably at least 70%, and more preferably at least 90% of fibers **8** of deformation **6** have a significant, and more preferably, a major vector component parallel to transverse axis **T**. Fiber orientation can be determined by use of magnifying means if necessary, such as a microscope fitted with a suitable measurement scale. In general, for a non-linear segment of fiber viewed in plan view, a straight-line approximation for both longitudinal axis **L** and the looped fibers **8** can be used for determining the angle of looped fibers **8** from longitudinal axis **L**.

The orientation of looped fibers **8** in the deformations **6** of second region **4** is to be contrasted with the fiber composition and orientation of the first region **2**, which, for nonwoven precursor webs **20** is best described as having a substantially randomly-oriented fiber alignment. In a woven web embodiment, the orientation of the looped fibers **8** in deformations **6** could be the same as described above, but the fibers of second region **2** would have the orientation associated with the particular weaving process used to make the web, e.g., a square weave pattern.

In the embodiment shown in FIG. 1 the longitudinal axes **L** of deformations **6** are generally aligned in the **MD**. Deformations **6** and, therefore, longitudinal axes **L**, can, in principle, be aligned in any orientation with respect to the **MD** or **CD**. Therefore, in general, it can be said that for each deformation **6**, the looped aligned fibers **8** are aligned generally orthogonal to the longitudinal axis **L** such that they have a significant vector component parallel to transverse axis **T**, and more preferably a major vector component parallel to transverse axis **T**.

FIG. 5 is a scanning electron microscope (SEM) photo of a web 1 similar to that described with respect to FIG. 1. The web 1 of FIG. 5 is a 70 gsm spunbond nonwoven web comprising polyethylene/polypropylene (sheath/core) bicomponent fibers. The perspective of FIG. 5 is essentially a side view of the first surface 2 and deformations 6 of web 1. By “side view” is meant that the photo of FIG. 5 is taken generally in the CD direction as indicated in FIGS. 1-4, such that the MD and longitudinal axes L of each deformation 6 are oriented across (e.g., generally horizontally) in FIG. 5. As shown in FIG. 5, deformations 6 comprise looped aligned fibers 8 are aligned generally orthogonal to the longitudinal axis L and have at least a significant vector component parallel to transverse axis T.

In some embodiments, due to the preferred method of forming deformations 6, as described below, another characteristic of deformations 6 is their generally open structure characterized by open void area 10 defined interiorly of deformations 6, as shown in FIG. 3. The void area 10 may have a shape that is wider or larger at the distal 3 end of deformation 6 and narrower at the base 5 of the deformation 6. This shape is opposite to the shape of the tooth which is used to form the deformation 6. By “void area” is not meant completely free of any fibers, but is meant as a general description of its general appearance. Therefore, it may be that in some deformations 6 a loose fiber 8 or a plurality of loose fibers 8 may be present in the void area 10. By “open” void area is meant that the two longitudinal ends of deformation 6 are generally open and free of fibers, such that deformation 6 forms something like a “tunnel” structure, as shown in FIG. 3. For example, FIG. 6 is a close-up SEM view of one deformation 6 of the web 1 shown in FIG. 5. As shown, in addition to the looped aligned fibers 8 there is a distinct open void area 10 defined by a plurality of looped aligned fibers 8. Very few broken fibers 18 are visible. As can be seen, the base 5 of the deformation 6 may be closed (as in the fibers forming the deformation 6 are close enough together to touch) or may remain open. Generally, any opening at the base 6 is narrow.

Additionally, as a consequence of a preferred method of making web 1, the second regions 4 associated with second surface 14 are discontinuities 16 characterized by a generally linear indentation defined by formerly random fibers of the second surface 14 having been urged directionally (i.e., the “Z -direction” as is commonly understood in the nonwoven art to indicate an “out-of-plane” direction generally orthogonal to the MD-CD plane as shown in FIGS. 1 and 3) into deformation 6 by the teeth of the forming structure, described in detail below. The abrupt change of orientation exhibited by the previously randomly-oriented fibers of precursor web 20 defines the discontinuity 16, which exhibits a linearity such that it can be described as having a

longitudinal axis generally parallel to longitudinal axis **L** of the deformation **6**. Due to the nature of many nonwoven webs useful as precursor webs **20**, discontinuity **16** may not be as distinctly noticeable as deformations **6**. For this reason, the discontinuities **16** on the second side of web **1** can go unnoticed and may be generally undetected unless web **1** is closely inspected. Thus in some embodiments, web **1** has the look and feel of terry cloth on a first side, and a relatively smooth, soft look and feel on a second side. In other embodiments, discontinuities **16** can appear as apertures, and may be apertures through web **1** via the ends of the tunnel-like looped deformations **6**.

Further, as a consequence of a preferred method of making web **1**, whether or not the second regions **4** have looped aligned fibers **8**, each exhibits a pronounced linearity at or near the first and second surfaces **12**, and **14**, respectively, of web **1**. As disclosed more fully below with respect to the method of making, one can appreciate that, due to the geometry of teeth **110** of roll **104**, the second regions **4** of precursor web **20** each have a linear orientation associated therewith. This linear orientation is an inevitable consequence of the method of making web **1** as described herein. One way of understanding this linear orientation is to consider the linear orientation of discontinuities **16** on the second surface **14** of web **1**. Likewise, if deformation **6** were removed from web **1** at first surface **12**, the second region **4** would appear as a linear discontinuity on the first surface **12** of web **1**, e.g., as if a linear slit or cut had been made in precursor web **20** at the location of deformation **6**. This linear web discontinuity corresponds directionally to longitudinal axis **L**.

From the description of web **1**, it can be seen that the looped fibers **8** of deformation **6** can originate and extend from either the first surface **12** or the second surface **14** of web **1**. Of course the fibers **8** of deformation **6** can also extend from the interior **19** of web **1**. The fibers **8** of deformations **6** extend due to having been urged out of the generally two-dimensional plane of precursor web **20** (i.e., urged in the “Z-direction” as shown in FIG. 3). In general, the fibers **8** or **18** of the second regions **4** comprise fibers that are integral with and extend from the fibers of the fibrous web first regions **2**.

Therefore, from the above description, it is understood that in one embodiment web **1** can be described as being a fibrous web **1** having a first surface **12** and a second surface **14**, the fibrous web **1** comprising a first region **2** and a plurality of discrete integral second regions **4**, the second regions **4** having at least one portion being a discontinuity **16** exhibiting a linear orientation and defining a longitudinal axis **L** and at least another portion being a deformation **6** comprising a plurality of tufted fibers integral with but extending from the first region **2**.

The extension of looped fibers **8** can be accompanied by a general reduction in fiber cross sectional dimension (e.g., diameter for round fibers) due to plastic deformation of the fibers and the effects of Poisson's ratio. Therefore, the fibers **8** of deformation **6** can have an average fiber diameter less than the average fiber diameter of the fibers of precursor web **20** as well as the fibers of first regions **2**. It is believed that this reduction in fiber diameter contributes to the perceived softness of the web **1**, a softness that can be comparable to cotton terry cloth, depending on the material properties of the precursor web **20**. It has been found that the reduction in fiber cross-sectional dimension is greatest intermediate the base **5** and the distal portion **3**. This is believed to be due to the method of making, as disclosed more fully below. Briefly, it is believed that portions of fibers at the base **5** and distal portion **3** of deformations **6** are adjacent the tip of teeth **110** of roll **104**, described more fully below, and are frictionally locked and immobile during processing. Thus, the intermediate portions of deformations **6** are more free to stretch, or elongate, and accordingly, are more free to experience a corresponding fiber cross sectional dimension reduction.

Referring to FIG. 7 there is shown in an apparatus and method for making web **1** of the present invention. The apparatus **100** comprises a pair of intermeshing rolls **102** and **104**, each rotating about an axis **A**, the axes **A** being parallel in the same plane. Roll **102** comprises a plurality of ridges **106** and corresponding grooves **108** which extend unbroken about the entire circumference of roll **102**. Roll **104** is similar to roll **102**, but rather than having ridges that extend unbroken about the entire circumference, roll **104** comprises a plurality of rows of circumferentially-extending ridges that have been modified to be rows of circumferentially-spaced teeth **110** that extend in spaced relationship about at least a portion of roll **104**. The individual rows of teeth **110** of roll **104** are separated by corresponding grooves **112**. In operation, rolls **102** and **104** intermesh such that the ridges **106** of roll **102** extend into the grooves **112** of roll **104** and the teeth **110** of roll **104** extend into the grooves **108** of roll **102**. The intermeshing is shown in greater detail in the cross sectional representation of FIG. 8, discussed below. Both or either of rolls **102** and **104** can be heated by means known in the art such as by using hot oil filled rollers or electrically-heated rollers.

In FIG. 7, the apparatus **100** is shown in a preferred configuration having one patterned roll, e.g., roll **104**, and one non-patterned grooved roll **102**. However, in certain embodiments it may be preferable to use two patterned rolls **104** having either the same or differing patterns, in the same or different corresponding regions of the respective rolls. Such an apparatus can produce webs with deformations protruding from both sides of the web **1**.

The method of making a web **1** of the present invention in a commercially viable continuous process is depicted in FIG. 7. Web **1** is made by mechanically deforming a precursor web **20** that can be described as generally planar and two-dimensional. By “planar” and “two dimensional” is meant simply that the web is flat relative to the finished web **1** that has distinct, out-of-plane, Z-direction three-dimensionality imparted due to the formation of second regions **4**. “Planar” and “two-dimensional” are not meant to imply any particular flatness, smoothness or dimensionality.

The process described is similar in many respects to a process as described in U.S. Pat. No. 5,518,801 entitled “Web Materials Exhibiting Elastic-Like Behavior” and referred to in subsequent patent literature as “SELF” webs, which stands for “Structural Elastic-like Film”. However, there are significant differences between the apparatus of the present invention and the apparatus disclosed in the above-identified ‘801 patent. These differences account for the novel features of the web of the present invention. As described below, the teeth **110** of roll **104** have a specific geometry associated with the leading and trailing edges that permit the teeth, e.g., teeth **110**, to essentially “punch” through the precursor web **20** as opposed to, in essence, emboss the web. The difference in the apparatus **100** of the present invention results in a fundamentally different web. For example, a web **1** of the present invention can have distinctive “tunnel-like” tufted deformations **6** of looped, aligned fibers **8**, unlike the “tent-like” rib-like elements of prior art SELF webs which each have continuous side walls associated therewith, i.e., a continuous “transition zone.” It is believed that the distinctive “tunnel-like” tufted deformations **6** of the web **1** of the present invention contribute to the superior fluid handling properties of web **1** by permitting fluid entry into and through web **1** via void regions **10** of deformations **6**.

Precursor web **20** is provided either directly from a web making process or indirectly from a supply roll (neither shown) and moved in the machine direction to the nip **116** of counter-rotating intermeshing rolls **102** and **104**. Precursor web can be a nonwoven web comprising any of known fiber types, including bicomponent fibers, capillary channel fibers, microfibers or splittable fibers. Precursor web **20** can be preheated by means known in the art, such as by heating over oil-heated rollers. Furthermore, precursor web can be a nonwoven web made by known processes, such as meltblown, spunbond, and carded. As precursor web **20** goes through the nip **116** the teeth **110** of roll **104** enter grooves **108** of roll **102** and simultaneously urge fibers out of the plane of plane of precursor web **20** to form second regions **2**, including deformations **6** and discontinuities **16**. In effect, teeth **110** “push” or “punch” through precursor web **20**. As the tip of teeth **110** push through precursor web **20** the portions of fibers that are oriented

predominantly in the **CD** and across teeth **110** are urged by the teeth **110** out of the plane of precursor web **20** and are stretched, pulled, and/or plastically deformed in the Z-direction, resulting information of second region **4**, including the looped fibers **8** of deformations **6** of web **1**. Fibers that are predominantly oriented generally parallel to the longitudinal axis **L**, i.e., in the machine direction of precursor web **20** as shown in FIG. 1, are simply spread apart by teeth **110** and remain substantially in the first region **2** of web **1**. Although, as discussed more fully below, it has been found that the rate of formation of deformations **6** affects fiber orientation, in general, and at least at low rates of formation, it can be understood why the looped fibers **8** can exhibit the unique fiber orientation which is a high percentage of fibers having a significant or major vector component parallel to the transverse axis **T** of deformation **6**, as discussed above with respect to FIGS. 3 and 4. In general, at least some of the fibers of deformation **6** are looped, aligned fibers **8** which can be described as having a significant or major vector component parallel to a Z-oriented plane orthogonal to transverse axis **T**.

The number, spacing, and size of deformations **6** can be varied by changing the number, spacing, and size of teeth **110** and making corresponding dimensional changes as necessary to roll **104** and/or roll **102**. This variation, together with the variation possible in precursor webs **20** and line speeds, permits many varied webs **1** to be made for many purposes. For example, web **1** made from a high basis weight textile fabric having **MD** and **CD** woven extensible threads could be made into a soft, porous ground covering, such as a cow carpet useful for reducing udder and teat problems in cows. A web **1** made from a relatively low basis weight nonwoven web of extensible spunbond polymer fibers could be used as a terry cloth-like fabric for semi-durable or durable clothing. As described more fully below, web **1** can also be used in disposable absorbent articles.

FIG 8 shows in cross section a portion of the intermeshing rolls **102** and **104** including ridges **106** and teeth **110**. As shown teeth **110** have a tooth height **TH** (note that **TH** can also be applied to ridge **106** height; in a preferred embodiment tooth height and ridge height are equal), and a tooth-to-tooth spacing (or ridge-to-ridge spacing) referred to as the pitch **P**. As shown, depth of engagement **E** is a measure of the level of intermeshing of rolls **102** and **104** and is measured from tip of ridge **106** to tip of tooth **110**. The depth of engagement **E**, tooth height **TH**, and pitch **P** can be varied as desired depending on the properties of precursor web **20** and the desired characteristics of web **1**. For example, in general, to obtain looped fibers in deformation **6**, the greater the level of engagement **E**, the greater the necessary fiber mobility and/or elongation characteristics the fibers of precursor web **20** must possess. Also, the greater the density of

second regions **4** desired (second regions **4** per unit area of web **1**), the smaller the pitch should be, and the smaller the tooth length **TL** and tooth distance **TD** should be, as described below.

FIG. 9 shows one embodiment of a roll **104** having a plurality of teeth **110** useful for making a terry cloth-like web **1** of spunbond nonwoven material from a spunbond nonwoven precursor web **20** having a basis weight of between about 60 gsm and 100 gsm, preferably about 70 gsm, or 80 gsm or 90 gsm. An enlarged view of teeth **110** shown in FIG. 9 is shown in FIG. 10. In this embodiment of roll **104** teeth **110** have a uniform circumferential length dimension **TL** of about 1.25 mm measured generally from the leading edge **LE** to the trailing edge **TE** at the tooth tip **111**, and are uniformly spaced from one another circumferentially by a distance **TD** of about 1.5 mm. For making a terry-cloth web **1** from a precursor web **20** having a basis weight in the range of about 60 to 100 gsm, teeth **110** of roll **104** can have a length **TL** ranging from about 0.5 mm to about 3 mm and a spacing **TD** from about 0.5 mm to about 3 mm, a tooth height **TH** ranging from about 0.5 mm to about 10 mm, and a pitch **P** between about 1 mm (0.040 inches) and 2.54 mm (0.100 inches). Depth of engagement **E** can be from about 0.5 mm to about 5 mm (up to a maximum approaching the tooth height **TH**). Of course, **E**, **P**, **TH**, **TD** and **TL** can each be varied independently of each other to achieve a desired size, spacing, and area density of deformations **6** (number of deformations **6** per unit area of web **1**).

As shown in FIG. 8, each tooth **110** has a tip **111**, a leading edge **LE** and a trailing edge **TE**. The tooth tip **111** is elongated and has a generally longitudinal orientation, corresponding to the longitudinal axes **L** of second regions **4**. It is believed that to get the tufted deformations **6** of the web **1** that can be described as being terry cloth-like, the **LE** and **TE** should be very nearly orthogonal to the local peripheral surface **120** of roll **104**. As well, the transition from the tip **111** and the **LE** or **TE** should be a sharp angle, such as a right angle, having a sufficiently small radius of curvature such that, in use the teeth **110** push through precursor web **20** at the **LE** and **TE**. Without being bound by theory, it is believed that having relatively sharply angled tip transitions between the tip of tooth **110** and the **LE** and **TE** permits the teeth **110** to punch through precursor web **20** “cleanly”, that is, locally and distinctly, so that the resulting web **1** can be described as “tufted” in second regions **4** rather than “embossed” for example. When so processed, the web **1** is not imparted with any particular elasticity, beyond what the precursor web **20** may have possessed originally.

It has been found that line speed, that is, the rate at which precursor web **20** is processed through the nip of rotating rolls **102** and **104**, and the resulting rate of formation of deformations **6**, impacts the structure of the resulting deformations **6**. For example, the deformations **6** shown

in FIGS. 5 and 6 were made at a relatively low rate of approximately 3 meters per minute (m/min) (about 10 feet per minute). Three m/min is considered a relatively slow rate for commercial production for many consumer applications, but for the spunbond bicomponent fibers used in the nonwoven web shown in FIGS. 5 and 6 this relatively slow speed resulted in very uniform, looped, aligned fibers 8 in deformations 6.

At higher line speeds, i.e., relatively higher rates of processing through the nip of rotating rolls 102 and 104, like materials can exhibit very different structures for deformations 6, i.e., tufts. For example, FIGS. 11 and 12 show representative deformations 6 for webs 1 made from the same material with the same process conditions, the only difference being the rotational speed of the rolls 102 and 104, i.e., line speed (in units of length/time) of the precursor web 20 being processed into web 1. The precursor web 20 used for each of the webs shown in FIGS. 11 and 12 was a 25 gsm nonwoven web comprising polypropylene and available from BBA Nonwovens, Simpsonville, SC, and sold under the trade name Sofspan 200®. The web shown in FIG. 11 was processed through the nip 116 of rolls 102 and 104 having a depth of engagement E of about 3.4 mm (about 0.135 inch), a pitch P of about 1.5 mm (about 0.060 inch), a tooth height TH, of about 3.7 mm (about 0.145 inch), a tooth distance of TD of 1.6 mm (about 0.063 inch), and a tooth length of TL of about 1.25 mm (about 0.050 inch). The web was run at a line speed of about 15 meters/minute (about 50 feet per minute). The web shown in FIG. 12 is identical to the web shown in FIG. 11, and was processed under identical conditions except for the line speed, which was about 150 meters per minute (about 500 feet per minute).

As can be seen from an inspection of FIGS. 11 and 12, the deformations 6 shown are noticeably different. The deformation 6 shown in FIG. 11 is similar in structure to the deformations shown in FIGS. 1-6. That is, it exhibits substantially aligned, looped fibers 8 with very few broken fibers, e.g., fibers 18 as shown in FIG 3. The deformation 6 shown in FIG. 12, however, exhibits a very different structure, a structure that appears to be typical of spunbond nonwoven materials processed to form deformations 6 at relatively high speeds. Typical of this structure is broken fibers between the proximal portion, i.e., base 5, of deformations 6 and the distal portion, i.e., the top 3, of deformations 6, and what appears to be a "mat" 7 of fibers at the top of the deformation 6. Mat 7 comprises and is supported at the top of deformations 6 by unbroken, looped fibers 8, and also comprises portions of broken fibers 11 that are no longer integral with precursor web 20. That is, mat 7 comprises fiber portions which were formerly integral with precursor web 20 but which are completely detached from precursor web 20 after

processing at sufficiently high line speeds in the process described with reference to FIGS. 7 and 8.

Therefore, from the above description, it is understood that in one embodiment web **1** can be described as being a fibrous web **1** having a first surface **12** and a second surface **14**, the fibrous web **1** comprising a first region **2** and a plurality of discrete second regions **4**, the second regions **4** having at least one portion being a discontinuity **16** exhibiting a linear orientation and defining a longitudinal axis **L** and at least another portion being a deformation **6**, the deformation **6** comprising fibers integral with but extending from first region **2** and fibers neither integral with nor extending from first region **2**.

Another example of webs **1** being identical in material and processing except for line speed is shown with respect to FIGS. 13 and 14. The precursor web **20** for each web **1** shown in FIGS. 13 and 14 was a 60 gsm spunbond nonwoven web available from BBA Nonwovens, Simpsonville, SC, and sold under the trade name Sofspan 200®. The web shown in FIG. 13 was processed through the nip **116** of rolls **102** and **104** having a depth of engagement **E** of about 3.4 mm (about 0.135 inch), a pitch **P** of about 1.5 mm (about 0.060 inch), a tooth height **TH**, of about 3.7 mm (about 0.145 inch), a tooth distance of **TD** of about 1.6 mm (about 0.063 inch), and a tooth length of **TL** of about 1.25 mm (about 0.050 inch). The web was run at a line speed of about 15 meters/minute (about 50 feet per minute). The web shown in FIG. 14 is identical to the web shown in FIG. 13, and was processed under identical conditions except for the line speed, which was about 150 meters per minute (about 500 feet per minute).

The web **1** shown in FIG. 13 was processed at a line speed of about 15 meters per minute (about 50 feet per minute). As shown, even at this relatively moderate line speed, some amount of matting at the distal end of deformation **6** is noticed. This matting, which appears to be a higher density of flattened, compressed fiber portions, occurs on the portion of deformation **6** associated during manufacturing with the tip of tooth **110** of roll **104**. As line speed is increased, this matting, i.e., mat **7**, becomes more distinct, as shown in FIG. 14, which shows a web processed under identical conditions as the web shown in FIG. 13, but was processed at a line speed of about 150 meters per minute (about 500 feet per minute). The deformations **6** shown in FIG. 14 exhibit a more distinct mat **7** and can be described as comprising fibers **8** or **18** integral with but extending from first region **2** and fibers **11** (in mat **7**) which are neither integral with nor extending from first region **2**.

It is believed that the distinct fiber orientation observed at the distal portion of deformations **6**, e.g., mat **7**, is due primarily to processing rates, it is also believed to be affected

by other parameters, such as fiber type and basis weight of the precursor web **20** as well as processing temperatures that can affect the degree of fiber-to-fiber bonding. For example, as observed above, matting of fibers occurs on the portion of deformation **6** associated during manufacturing with the tip of tooth **110** of roll **104**. It is believed that frictional engagement of the fibers at the tip of the teeth "lock" the fibers in place, thereby limiting fiber elongation and/or fiber mobility, two mechanisms believed to permit formation of deformations **6**. Therefore, once locked, so to speak, in position, fibers adjacent tooth **110** tip can be broken, and, due to the random entanglement of the precursor web as well as possible cold welding of fibers due to pressure and friction, the broken fibers **11** become and remain lodged in mat **7** at the distal end **3** of deformations **6**.

Precursor webs **20** having relatively higher basis weights generally have relatively more fiber **11** portions in mat **7**. In one sense, it appears as is most of the fiber content of the precursor web **20** in the immediate vicinity of a tooth tip **110** during manufacture is simply displaced in the Z-direction to the distal portion **3** of deformations **6**, resulting in mat **7**. Precursor webs **20** comprising relatively low elongation fibers, or fibers with relatively low fiber-to-fiber mobility (e.g., relatively limited capability for fiber reptation) appear to result in relatively few fibers becoming and remaining lodged in mat **7** at the distal end **3** of deformations **6**. Fiber-to-fiber mobility can be increased by reducing or eliminating the fiber-to-fiber bonds. Thermal bonds can be completely eliminated, or significantly reduced in certain nonwoven webs to increase fiber-to-fiber mobility. Similarly, hydroentangled web can be less entangled to increase fiber-to-fiber mobility. For any precursor web **20** lubricating it prior to processing as disclosed herein can also increase fiber-to-fiber mobility. For example, a mineral oil lubricant can be applied to precursor web **20** prior to it entering the nip **116** of rolls **102** and **104**.

The result of the presence of mats **7** is a web **1** having a slightly rougher, textured impression on one side thereof, useful, for example, for wipes in which more scrubbing texture is desirable. In one sense a web having soft terry cloth-like tactile impression when made under relatively low-speed processing conditions, can have the feel of a cheap hotel towel when processed under identical, but relatively higher line speed conditions. This rough, textured tactile impression on a fibrous web can be useful for some applications, such as for a hard surface cleaning wipe or an exfoliating facial wipe.

It has been found that certain nonwoven webs, such as carded webs comprising staple-length fibers, produce very few looped fibers **8** in deformations **6**, so that the deformations **6** produced in these webs cannot be described as comprising a plurality of looped, aligned fibers **8**

as described above with respect to FIGS. 1-6. Instead, as shown in the SEM photograph of FIG. 17, carded nonwoven webs can produce deformations **6** having few, if any, looped, aligned fibers **8**, and many, if not all, non-aligned fibers and/or broken fibers **18**. The precursor web **20** used to make the web **1** shown in FIG. 17 was a 40 gsm carded web available from BBA Nonwovens, Simpsonville, SC, as High Elongation Carded (HEC®) and was processed through the nip **116** of rolls **102** and **104** having a depth of engagement **E** of about 3.4 mm (about 0.135 inch), a pitch **P** of about 1.5 mm (about 0.060 inch), a tooth height **TH**, of about 3.7 mm (about 0.145 inch), a tooth distance of **TD** of about 1.6 mm (about 0.063 inch), and a tooth length of **TL** of about 1.25 mm (about 0.050 inch). The web was run at a line speed of about 15 meters/minute (about 50 feet per minute). It is believed that the non-alignment of fibers in deformations **6** made from carded webs is due in part to the nature of the fiber content of carded webs. Staple fibers are not “endless,” but instead have a predetermined length on the order of 25 mm to about 400 mm, and, more typically from about 40 mm to about 80 mm. Therefore, when a carded web is processed by the apparatus described with respect to FIG. 7, it is believed that there is a much greater likelihood that a loose fiber end will be in the vicinity of a deformation **6** and thus produce a non-looped fiber end in deformation **6**. Furthermore, often staple fibers do not have the same elongation characteristics of spunbond or meltblown fibers, for example. However, even if deformations **6** have no looped fibers, the fibrous tufts nevertheless provide a softness benefit and produce a web having terry cloth-like characteristics.

Therefore, from the above description, it is understood that the web of the present invention need not have looped, aligned fibers, and in one embodiment can be described as being a fibrous web **1** formed by selective mechanical deformation of a precursor web **20** having a first surface **12** and a second surface **14** and comprising substantially randomly-oriented fibers, the fibrous web comprising a first region of substantially randomly-oriented fibers being substantially free of deformation by the selective mechanical deformation, and a plurality of discrete integral second regions, the second regions **4** comprising spaced-apart deformations **6** of the precursor web **20**, each of the second regions **4** having at least one portion being a discontinuity **16** exhibiting a linearity and defining a longitudinal axis **L** and at least another portion comprising a plurality of tufted fibers integral with but extending from said first region.

Webs **1** of the present invention offer many opportunities for producing engineered materials having selected characteristics. For example, a web **1** can be made by selecting the length of staple fibers in a carded precursor web **20** so that the probability of having fiber ends exposed in deformations **6** can be reliably predicted. Also, a carded web of staple fibers can be

blended or laminated with a spunbond nonwoven web to produce a hybrid, such that the deformations 6 of second regions 4 comprise primarily looped spunbond fibers and the first regions 2 comprise both carded and spunbond fibers. The type of fibers, the length of staple fibers, the layering of fibers, and other variations of precursor web 20 can be varied as desired to produce desired functional characteristics of the web 1.

If a woven precursor web 20 is utilized, the formation and structure of second regions 4 can be very close to the same as that exhibited by webs 1 formed from nonwoven webs. For example, if a woven precursor web 20 has warp or weft threads having sufficient elongation properties and being predominantly oriented in a cross machine direction, upon being processed by the apparatus 100 described above, the teeth 110 tend to separate the machine direction threads (either warp or weft) and only urge out of plane the cross-machine direction threads. Thus, the web 1 produced from a woven precursor web 20 can look and feel very much like terry cloth fabric.

In preferred embodiments precursor web 20 is a nonwoven web in which there are minimal fiber-to-fiber bonds. For example, the precursor web can be a nonwoven web having a pattern of discrete thermal point bonds, as is commonly known in the art for nonwoven webs. In general, however, it is desirable to minimize the number and spacing of bond points so as to allow for maximum fiber mobility and dislocation at the second regions 4 of web 1. In general, utilizing fibers having relatively high diameters, and/or relatively high extension to break, and/or relatively high fiber mobility, results in better and more distinctly formed second regions 4, specifically deformations 6.

Although web 1 is disclosed in preferred embodiments as a single layer web made from a single layer precursor web 20, it is not necessary that it be so. For example, a laminate or composite precursor web 20 having two or more layers or plies can be used. In general, the above description for web 1 holds, recognizing that looped aligned fibers 8, for example, formed from a laminate precursor web would be comprised of fibers from both (or all) layers of the laminate. In such a web structure, it is important, therefore, that all the fibers of all the layers have sufficient diameter, elongation characteristics, and fiber mobility, so as not to break prior to extension and deformation. In this manner, fibers from all the layers of the laminate may contribute to the tufted deformations 6. In a multilayer web, the fibers of the different webs may be mixed or intermingled in the deformation 6. The fibers do not protrude through but combine with the fibers in an adjacent web. This is often observed when the webs are processed at very high speeds.

Multilayer webs **1** can have significant advantages over single layer webs **1**. For example, a deformation **6** from a multilayer web **1** using two precursor webs **20A** and **20B** is shown schematically in FIGS. 18-20. As shown, both precursor webs **20A** and **20B** contribute fibers to deformations **6** in a “nested” relationship that “locks” the two precursor webs together, forming a laminate web without the use or need of adhesives or thermal bonding between the layers. However, if desired an adhesive, chemical bonding, resin or powder bonding, or thermal bonding between the layers can be selectively utilized to certain regions or all of the precursor webs. In addition, the multiple layers may be bonded during processing, for example, by extruding a film onto a nonwoven or carding one layer of nonwoven onto a spunbond and thermal point bonding the combined layers. In a preferred embodiment, the deformations **6** retain the layered relationship of the laminate precursor web, as shown in FIG. 18, and in all preferred embodiments the upper layer (specifically layer **20A** in FIGS. 18-20, but in general the top layer with reference to the Z-direction as shown in FIGS. 18-20) remains substantially intact and forms looped fibers **8**.

In a multilayer web **1** each precursor web can have different properties. For example, web **1** can comprise two (or more) precursor webs, e.g., first and second precursor webs **20A** and **20B**. First precursor web **20A** can form an upper layer exhibiting high elongation and significant elastic recovery which enables the web **20A** to spring back. The spring back helps to laterally squeeze the base portion **5** of the deformation **6** of both webs as shown in FIG. 18. The spring back or lateral squeeze also helps to secure and stabilize the Z-oriented fibers in the deformation **6**. The lateral squeeze provided by precursor web **20A** can also increase the stability of the second precursor web **20B**. An example of a multilayer web **1** being identical in material and processing except for the line speed is shown with respect to FIGS. 15 and 16. Multilayer web **1** as shown in FIGS. 15 and 16 includes a first precursor web **20A** comprised of spunbond PE/PP sheath/core nonwoven web made by BBA, Washougal WA. The second precursor web **20B** is comprised of a thermal point bonded carded PET/Co-PET nonwoven web (50% 6dpf PET Wellman Type 204 made in Charlotte NC and 50% 6 dpf Co-PET Kanematsu Type LM651 made in Gastonia NC. The second precursor web **20B** can be loosely bonded to enable tufting so the lateral squeeze of the first precursor web **20A** can also increase the stability of the second precursor web **20B**. The multilayer webs **1** were both processed at a depth of engagement **E** of about 3.4 mm (about 0.135 inch). The multilayer web **1** shown in FIG 15 was processed at a slow speed, 3 meters per minute, and the multilayer web **1** shown in FIG. 16 was processed at a high speed, of 150 meters per minute. As can be seen, the fibers from the first and second precursor webs **20A** and **20B** in the deformation **6** in FIG. 16 (high speed processing) are much more

intermingled than those shown in FIG. 15 (slow speed processing). The multilayer web **1** can be utilized as a body-contacting layer when used as a topsheet on a disposable absorbent article.

In a multilayer web **1** each precursor web can have different material properties, thereby providing web **1** with beneficial properties. For example, web **1** comprising two (or more) precursor webs, e.g., first and second precursor webs **20A** and **20B** can have beneficial fluid handling properties for use as a topsheet on a disposable absorbent article, as described more fully below. For superior fluid handling, for example, first precursor web **20A** can form an upper layer (i.e., a body-contacting when used as a topsheet on a disposable absorbent article) and be comprised of relatively hydrophobic fibers. Second precursor web **20B** can form a lower layer (i.e., disposed between the topsheet and an absorbent core when used on a disposable absorbent article) comprised of relatively hydrophilic fibers. Fluid deposited upon the upper, relatively hydrophobic layer is quickly transported to the lower, relatively hydrophilic, layer. One reason for the observed rapid fluid transport is the capillary structures formed by the generally aligned fibers **8**, **18** of deformations **6**. The fibers **8**, **18** form directionally-aligned capillaries between adjacent fibers, and the capillary action is enhanced by the general convergence of fibers near proximal portion **5** of deformations **6**.

It is believed that the rapid fluid transport is further increased due to the ability of fluid to enter the web **1** via the voids **10** created by deformations **6**. This "lateral entry" capability and/or capillary action, and/or the hydrophilicity gradient afforded by the structure of web **1** makes web **1** an ideal material for optimal fluid handling for disposable absorbent articles. In particular, a multilayer web **1** can provide for even greater improvement in fluid handling characteristics. In another embodiment, first precursor web **20A** can be comprised of relatively soft fibers (e.g., polyethylene), while second precursor web **20B** can be comprised of relatively stiff fibers (e.g., polyester). In such a multilayer web **1**, deformations **6** can retain or recover a certain amount of height **h**, even after applied pressure. The benefit of such a structure, particularly when combined with a hydrophilicity gradient as described above (fibers can be rendered hydrophobic or hydrophilic by means known in the art), is a web **1** suitable for use as a topsheet in feminine hygiene products that provides for superior fluid acquisition and superior rewet properties (i.e., reduced fluid movement back to the surface of the topsheet). It is believed that the increased stiffness provided by the relatively stiff fibers of second precursor web **20B** provide for increased compression resistant caliper (thickness) of the web, while the relatively soft fibers of first precursor web **20A** provides for softness at the web/skin interface. This extra caliper, together with the ability of the distally-disposed portions **3** of deformations **6** to remain relatively soft and

relatively fluid free, results in a superior, soft, dry (and dry-feeling) topsheet for use in feminine hygiene products, as well as baby diapers, adult incontinence articles, bandages, and the like.

FIGS. 18-20 show representative schematic diagrams of possible structures for deformation 6, depending on the material properties of precursor webs 20A or 20B. Other structures, not shown, can be achieved, with the only limitation to various structures being the limitations inherent in the material properties of the precursor webs.

Therefore, as can be seen from the above description, depending on the precursor web 20 (or webs) utilized and the dimensional parameters of rolls 102 and 104, including teeth 110, web 1 of the present invention can exhibit a wide range of physical properties. The web 1 can exhibit a range of texture subjectively experienced as ranging from softness to roughness, an absorbency ranging from non-absorbent to very absorbent, a bulkiness ranging from relatively low bulk to relatively high bulk; a tear strength ranging from low tear strength to high tear strength; an elasticity ranging from non-elastic to at least 100% elastically extensible, a chemical resistance ranging from relatively low resistance to high resistance, depending on the chemical considered, and many other variable parameters generally described as shielding performance, alkali resistance, opacity, wiping performance, water absorptivity, oil absorptivity, moisture permeability, heat insulating properties, weatherability, high strength, high tear force, abrasion resistance, electrostatic controllability, drape, dye-affinity, safety and the like. In general, depending on the elongation properties of the fibers of precursor web 20, the dimensions of apparatus 100 can be varied to produce a web 1 having a wide range of dimensions associated with second regions 4, including the height h (as shown in FIG. 22), and spacing, including the area density of discrete second regions 4).

Web 1 may be used for a wide variety of applications, including various filter sheets such as air filter, bag filter, liquid filter, vacuum filter, water drain filter, and bacterial shielding filter; sheets for various electric appliances such as capacitor separator paper, and floppy disk packaging material; various industrial sheets such as tacky adhesive tape base cloth, oil absorbing material, and paper felt; various wiper sheets such as wipers for homes, services and medical treatment, printing roll wiper, wiper for cleaning copying machine, and wiper for optical systems; hygiene or personal cleansing wiper such as baby wipes, feminine wipes, facial wipes, or body wipes, various medicinal and sanitary sheets, such as surgical gown, gown, covering cloth, cap, mask, sheet, towel, gauze, base cloth for cataplasm, diaper, diaper core, diaper acquisition layer, diaper liner, diaper cover, base cloth for adhesive plaster, wet towel, and tissue; various sheets for clothes, such as padding cloth, pad, jumper liner, and disposable underwear; various life material

5 sheets such as base cloth for artificial leather and synthetic leather, table top, wall paper, shoji-gami (paper for paper screen), blind, calendar, wrapping, and packages for drying agents, shopping bag, suit cover, and pillow cover; various agricultural sheets, such as cow carpets, cooling and sun light-shielding cloth, lining curtain, sheet for overall covering, light-shielding sheet and grass preventing sheet, wrapping materials of pesticides, underlining paper of pots for seeding growth; various protection sheets such as fume prevention mask and dust prevention mask, laboratory gown, and dust preventive clothes; various sheets for civil engineering building, such as house wrap, drain material, filtering medium, separation material, overlay, roofing, tuft and carpet base cloth, wall interior material, soundproof or vibration reducing sheet, and curing sheet; and various automobile interior sheets, such as floor mat and trunk mat, molded ceiling material, head rest, and lining cloth, in addition to a separator sheet in alkaline batteries.

FIG. 21 is a photomicrograph of a terry cloth-like nonwoven fabric web **1** made by the process of the present invention using a roll **104** as shown in FIGS. 9 and 10 and useful as a component of a disposable absorbent article (as shown below in FIG. 23). The precursor web **20** used for the web **1** shown in FIG. 21 was a spunbond nonwoven having a basis weight of about 80 gsm, and comprising polyethylene/polypropylene (sheath/core) polyethylene/polypropylene (sheath/core) bicomponent fibers having an average diameter of about 33 microns. The web **1** of FIG. 21 has about 24 deformations **6** per square centimeter and is folded with the folded edge visible to show more clearly a plurality of spaced apart, tufted, looped deformations **6** having a plurality of looped, aligned fibers **8**, each of which has an average fiber diameter of about 18 microns.

A single deformation **6** is shown in FIG. 22 with dimensions indicated. As shown in FIG. 10, for the web described with respect to FIG. 22, the void area **10** of tufted, looped, deformation **6** is typically generally circular or oblong in shape, having a major dimension, referred to as height **h**, that can be at least 1 mm. In general, the height is not considered to be critical to the operation of the web, but can be varied depending on the desired end use of web **1**. The height **h** can be from 0.1 mm to about 10 mm or more. A web **1** formed from a nonwoven precursor web **20** and having a look and feel of terry cloth should have a height **h** of about 1 mm to about 3 mm.

Table 1 below shows representative dimensions for representative apparatus and webs made thereon.

Table 1: Examples of Apparatus Dimensional Parameters and Web Dimensions

| Sample No. | Precursor Web | Pitch (P) <mm> (inches) | Engagement (E) <mm> (inches) | Tooth Height (TH) <mm> (inches) | Loop height (h) (mm) | Avg. Fiber Diameter of Precursor Web (μm) | Avg. Fiber Diameter of Loop Fiber (μm) |
|------------|-----------------------------------|-------------------------------|------------------------------------|---------------------------------------|-------------------------|--|---|
| 1 | 80 gsm spunbond PE/PP core/sheath | <1.5> (0.060) | <3.4> (0.135) | <3.7> (0.145) | 1.07 | 33 | 18 |
| 2 | 80 gsm spunbond PE/PP core/sheath | <1.5> (0.060) | <2.2> (0.085) | <3.7> (0.145) | 0.49 | 31 | 23 |
| 3 | 60 gsm spunbond PE/PP copolymer | <1.5> (0.060) | <3.4> (0.135) | <3.7> (0.145) | 1.10 | 23 | 14 |
| 4 | 60 gsm spunbond PE/PP copolymer | <1.5> (0.060) | <3.4> (0.135) | <3.7> (0.145) | 1.41 | 28 | 15 |

In Table 1 above, all Samples are available from BBA Nonwovens, Simpsonville, SC.

Samples 1 and 2 are sold under the trade name Softex®. Samples 3 and 4 are sold under the trade name Sofspan 200®.

FIG. 23 shows in partial cut away plan view a catamenial article, specifically a sanitary napkin, having as one of its components a web 1 of the present invention. In general, sanitary napkin 200 comprises a backsheet 202, a topsheet 206 and an absorbent core 204 disposed between the topsheet 206 and backsheet 202 which can be joined about a the periphery 210. Sanitary napkin 200 can have side extensions, commonly referred to as “wings” 208 designed to wrap the sides of the crotch region of the panties of the user of sanitary napkin 1. Topsheet 206 of sanitary napkin 200 comprises web 1 having deformations 6 on a body facing side thereof. Alternatively, web 1 could be used with the deformation 6 on side 12 opposite of the body-facing side and the second side 14 being the body-facing side. This may enable the discontinuities 16 to transport fluid into the deformations 6. Sanitary napkins, including topsheets for use as the body

facing surface thereof, are well known in the art and need no detailed description of various alternative and optional designs. Other catamenial articles, such as panty liners, interlabial devices, will also have similar structure as sanitary napkins. It is noted that web **1** can be used as, or as a component of, one or more of a backsheet, core material, topsheet, secondary topsheet, or wing material. For example, web **1** could have multiple layers and comprise the topsheet, secondary topsheet, core and/or backsheet of hygiene product.

Web **1** can be utilized as an absorbent core in a hygiene product. The web **1** in an absorbent core may have a relatively high basis weight and/or be comprised of several layers. Specifically, an absorbent core can comprise a fibrous web of randomly oriented fibers with respect to an X-Y plane. The core will comprise a first surface and a second surface. The first surface will comprise a plurality of discrete regions of fiber reorientation. Each discrete region will have a linear orientation defining a longitudinal axis in the X-Y plane and will comprise a plurality of fibers having portions reoriented in a direction substantially orthogonal to said X-Y plane.

Web **1** or a composite comprising web **1** can also be utilized as a fecal material storage element. Web **1** can be utilized as a secondary topsheet or sublayer when it is disposed under an apertured web or film to accept and hold low viscosity feces or viscous bodily waste away from a wearer's skin after defecation. Embodiments of the present invention having larger total three dimensional volume within the web or between the deformations **6** generally provide a greater capacity for storage of low viscosity feces. Absorbent articles employing such fecal material storage elements, or sublayers, are described in U.S. patents 5,941,864; 5,957,906; 6,018,093; 6,010,491; 6,186,992; and 6,414,215, among others.

FIG. 24 shows in partial cut away perspective view a catamenial tampon **300** having as one of its components a web **1** of the present invention. In general, tampon **300** comprises a compressed absorbent core **302** and a fluid permeable cover wrap **304** that covers absorbent core **302**. Cover wrap **304** may extend beyond one end of absorbent core **302** to form a skirt portion **306**. A removal means, such as string **308** can be provided to facilitate removal of the tampon after use. Tampons, including cover wraps for use as the body contacting surface thereof, are well known in the art and need no detailed description of various alternative and optional designs. However, it is noted that web **1** can be used as, or as a component of, one or more of a cover wrap, absorbent core material, or removal means material.

Another advantage of the process described to produce the webs of the present invention is that the webs can be produced in-line with other web production equipment or in-line with

disposable absorbent article production equipment. Additionally, there may be other solid state formation processes that can be used either prior to or after the process of the present invention. For example, portions of or all of a web could be processed according to the present invention and then apertured with a stretching process, such as one described in US Patent No. 5,658,639 to Curro et al. Alternatively, a material could be made into a composite through a variety of processes, such as one described in US Publication No. 2003/028,165A1 to Curro et al. or ring rolled, for example as in US Patent No. 5,167,897 to Weber et al. and then processed according to the present invention. The resulting webs can thus exhibit the combined benefits of these multiple material modifications.

As can be understood from the above description of webs **1** and apparatus **100** of the present invention, many various structures of webs **1** can be made without departing from the scope of the present invention as claimed in the appended claims. For example, webs **1** can be coated or treated with lotions, medicaments, cleaning fluids, anti-bacterial solutions, emulsions, fragrances, surfactants. Likewise, apparatus **100** can be configured to only form deformations **6** on a portion of the web **1**, or to form varying sizes or area densities of deformations **6**.

All documents cited in the Detailed Description of the Invention are, in relevant part, incorporated herein by reference; the citation of any document is not to be construed as an admission that it is prior art with respect to the present invention.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.